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# ANALYSIS OF BOARD GAMES IN THE TEACHING OF PRODUCTION ENGINEERING

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# PRESENTATION

Paper presented at the University of Taubaté, São Paulo Brazil, in partial fulfillment of the requirements for the master's degree in mechanical engineering with emphasis on Mechanical Production.

**ANALYSIS OF BOARD GAMES IN THE TEACHING OF PRODUCTION ENGINEERING**

***Abstract.*** *The main objective of this research was to find out which board games are currently being used in the teaching of production engineering. This was done through bibliographic research in the repositories of the main public and private universities, congress publications, events and databases of the CAPES portal. As a result, board games are currently used in Unicamp-SP, PUC-Campinas-SP and Federal University of Santa Catarina-Campus Joinville, for the teaching of logistics and productivity tools of Lean Manufacturing. The applications of these board games in teaching production engineering are based on game-based learning, which is an important active teaching methodology and that proposes the creation of social skills and competencies such as interpersonal relationship, communication, ethics, identify and solve problems and others, where only with the traditional teaching of content exposure would not be possible to develop.*

***Keywords:*** *Active Learning Methodology, Board Games, Game-Based Learning, Production Engineering Teaching.*

## 1. INTRODUCTION

The graduation of the engineer to act in the current socio-economic context, where the companies are inserted in a scenario of constant change and high competitiveness, demand of these professionals a set of own and acquired competences in order to respond with efficiency and quickness of problem solving and implementation of improvements (HERZER et al., 2016).

This concern appears in the portal of the Coordination for the Improvement of Higher Education Personnel (Capes), which seeks to improve the training of engineers, under the motto "more and better engineers". Pro- for the use of innovative means of teaching and learning, as well as the correction of deficiencies in the use of modern pedagogical methods, the use of laboratories and information and communication technologies, for better results in the learning processes (SOUZA CLIMACO, 2014).

One of the innovative means of teaching is Game Based Learning or abbreviated to GBL, which is an active teaching and learning methodology based on the use of digital games. Through different programs or educational applications, games are used for the purpose of learning, teaching, training and evaluation of students. Game-based learning also refers to the use of non-digital games for the same purposes, such as: card games, board games or dynamics that engage and keep students focused on the game's solution (TANG, HANNEGHAN & RHSLIBI, 2009) .

This research is justified by the need to explore new teaching techniques for training engineers that stimulate, in addition to training by academic knowledge, the development of skills for interpersonal relationships, group work, leadership, and others of a social nature, which only the involvement in game dynamics and other active teaching-learning methodologies can bring. In addition, non-digital games are not tied to maintenance structures, obsolescence and training of the computational technologies involved, making their use simpler and less expensive for higher education institutions.

Before the presentation was raised a question: are there recent developments of non-digital games, specifically board games, for use in teaching engineering disciplines in Brazil?

As a general objective, a bibliographical research was used to identify which board games a use and in which teaching institutions and their results in the use.

As a specific objective the dynamic characteristics of these games were raised, which areas of production engineering and didactic concepts approach.

This work is organized in the following chapters: 1-Introduction; 2-Theoretical Background; 3-Methodology; 4-Results and Discussion; 5-Conclusions and 6. References

## 2. THEORETICAL BACKGROUND

### 2.1 Engineer's Graduation

Social and economic changes have led companies to reinvent themselves by becoming leaner and ever-changing to survive in a highly competitive marketplace. This scenario creates demand for professionals from engineering courses that present diverse competences, not only the project but also the managerial ones (LOPES, 2016)

According to research by MACHADO, LUZ AND PAIVA (2015), the professional competences of engineers are composed of knowledge: knowledge; by the skills: the know-how, which is gained from the experience of the practical application of the studies; and by the attitudes: the knowing to be, that is connected to the characteristics of the personality and character of the professional and their social relations with the work, where skills are necessary to know how to work in a team, to deal with problem solving and conflicts, innovation and adaptation to change , communication and interpersonal relationships. The development of personal skills requires the application of pedagogical methods and processes to develop critical and reflexive attitudes, so that higher education institutions should seek dynamic and participatory forms, bringing the student closer to reality and transforming these from passive apprentices through practical teaching and reflective, on active managers.

The National Curricular guidelines of the undergraduate courses in engineering and the

guidelines of ENADE 2014 highlight specific competences that graduates must possess, among them interpersonal skills, such as: communication, ethics, identifying and solving problems, evaluating the social and economic impact of projects , among others (LOPES, 2016).

**2.2 Active learning**

According to CASTRO (2015) Engineering education must accompany the transformations in society caused by Information and Communication Technologies (ICTs), internationalization of capital and globalization, Institutions of Higher Education (IES) should review the strategies to develop the necessary skills that your students need to be able to act in this scenario.

It is up to teachers to apply strategies that ensure the encounter between students' cognitive relation and educational content. In this mediation the teacher should seek ways to ensure the students' learning by creating situations of active participation in this process of developing mental abilities and abilities (CASTRO, 2015).

Active learning methodologies, based on the philosophy of constructivism, where knowledge is not something that can be transmitted by the teacher, but must be built by the student, respecting his personal way of understanding the world. With the active learning methodologies the student is no longer a mere spectator of the classes but an active character in the construction of knowledge, working collaboratively in the search, elaboration and solution of problems, using for this the interdisciplinarity of the contents (KUO, CALADO E CALARGE, 2015)

Problem Based Learning (PBL), developed in the 1960s by McMaster University in Canada, is a teaching-learning method based on constructivism in which through the use of real-life problems, which can be simulated or experienced, students are motivated to learn the academic theories, skills, postures and attitudes necessary to solve problems in real life (SANTOS et al., 2014)

Several are the proposals used with Problem-Based Learning, among which the most used are: computer games, computer simulations, company games, dynamics, etc., being the teacher responsible for choosing the teaching-learning strategy that best suits the needs of their students (Butzke and Alberton, 2017).

**2.3 Company Games**

Company games date back more than 5,000 years, and have their origin as board games, where wars and battles in civilizations such as Egyptian and Hindu were simulated on a small scale (SOUSA, 2014).

These games had as background maps and with time they began to become more complex and serious, simulating strategies and tactics of war, in order to expand territories or to overcome

enemies. The first modern game of business simulation was created in 1956 by the American Management Association (AMA) the Top Management Decision Simulation, a computer game, interactive and generalist where students simulated a company to achieve the best market results for a product (RODRIGUES and SAUAIA, 2005).

Business games can be developed for computers or can also be developed more simply as board games, cards and paper games.

There are different applications and concepts involved in company games, but you can differentiate company games into two types: games and simulators, in the first there are clear rules and goals to be achieved, and there may or may not be a dispute between teams in a playful way. In the simulation there is no goal to be raised, but rather the best result is sought in a system, where it is possible in a controlled way to intervene in events, processes or phenomena. (MRTVI et al., 2017).

The researchers JEAN JUSTICE and RITZHAUPT (2015) present a study on the barriers and difficulties that institutions, teachers and students present for the implementation of computer games and simulators, such as: costs, difficulty in selecting the appropriate tool for content, difficulties in the teachers implement, adapt and follow the activities, difficulty to follow the students' learning in games or simulators, among others. This leading to the disincentive to implement these resources and when implemented to little use.

Both games and simulators raise the curiosity, the challenge and the need to propose and experience decision-making in search of problem solving, as well as defending and assuming results, developing skills and setting concepts, thus being excellent pedagogical means for training (SILVA et al., 2016).

They also present an important means to promote motivation for self-learning (TASPINAR, SCHMIDT and SCHUHBAUER, 2016).

**2.4 Board Games**

Although digital games have a dynamic and interactive look bigger than board games, they have been regaining their space and earning fans of video game buffs due to the latest commercial releases of non-educational board games that have a complexity and performance requirement of the players. One of the essential characteristics of this type of game is that it gathers people to face each other, and in digital games this interaction is unique with the computer platform, so it is considered individual games and non-digital games as collective (BARBARA, 2015).

Board games are used at all levels of education; they are composed of a base, usually cardboard called board, parts, cards and devices of randomness such as dice and wheels. In the board there are demarcations of positions or paths that must be followed by clear watering, and with

specific objectives to define the result. They are inexpensive and simple-to-play games, compared to computer games and have fun and engaging game dynamics (SAVI, 2011).

In a research by HUANG E LEVINSON (2012) on the application of board games for logistics teaching at a university in Minnesota, a group of students was evaluated in terms of learning styles and pedagogical objectives about the game. The study demonstrated that board games can also lead to disinterest and annoyance if the application is not well planned by the teacher, demonstrating to the students, before the application of the game, the concepts involved and expected objectives.

There have been few developments in non-digital gaming for engineering education, from the classic Beer Game created in the 1950s by the Massachusetts Institute of Technology (MIT), which simulates the behavior of a supply chain of production and distribution of beer, and that today still surprises its creators by the involvement of students, teamwork and the spirit of competition and is still played today in the format of board game (DIZIKES, 2013).

## 3. METHODOLOGY

This research may be classified as applied, it is characterized by its practical interest, that is, results are applied or used immediately in the solution of problems that occur in reality, the objectives is an exploratory research that would provide greater familiarity with the problem.

Regarding the approach of the problem, the research is qualitative according to GERHARDT, TATIANA ENGEL; SILVEIRA (2009) since it applies in researches where it is not possible to quantify certain aspects of reality and seeks to understand and explain the dynamics of social relations where one works with values, beliefs, motives, aspirations and attitudes through processes and phenomena that cannot be represented by numerical variables.

As for technical procedures, this is a bibliographical research which, according to Marconi and Lacoste (2008), does not presuppose a repetition of what has already been researched, but through the analysis of a theme under new aspects, it seeks to create an innovative conclusion.

It was elaborated by a research in national and international databases through the Portal of the Coordination of Improvement of University Level Personnel (CAPES), repositories of the main public and private universities, annals of meetings of engineering of production and congresses, through the search of such as: board games, game-based teaching, serious games, non-digital games, in Portuguese and English, selecting publications that specifically addressed the board games currently used in higher education institutions for the training of the production engineer in Brazil, demonstrating its characteristics, operating mechanics and academic concepts.

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## 4. RESULTS AND DISCUSSION

In Brazil the research brings the board games developed within large public and private universities, which are currently employed in the faculties of production engineering for the teaching of disciplines of logistics and production administration. We found three games in the board format that are presented below.

### 4.1 The Logistics Game

The Logistics Game is a simulation game for the distribution of products from Distribution Centers (CD) to final customers, developed by Prof. Dr. Marcos Ricardo Rosa Georges from PUC-Campinas (COTRIM, 2014) as a board game that presents as background the map of São Paulo, where 43 cities are interconnected by highways (Figure 1). The goal of the game is to represent, through the road modal, the different applications of logistics tools and concepts, such as: inventory management, CD localization, routing and scheduling of deliveries, logistics costs among others.

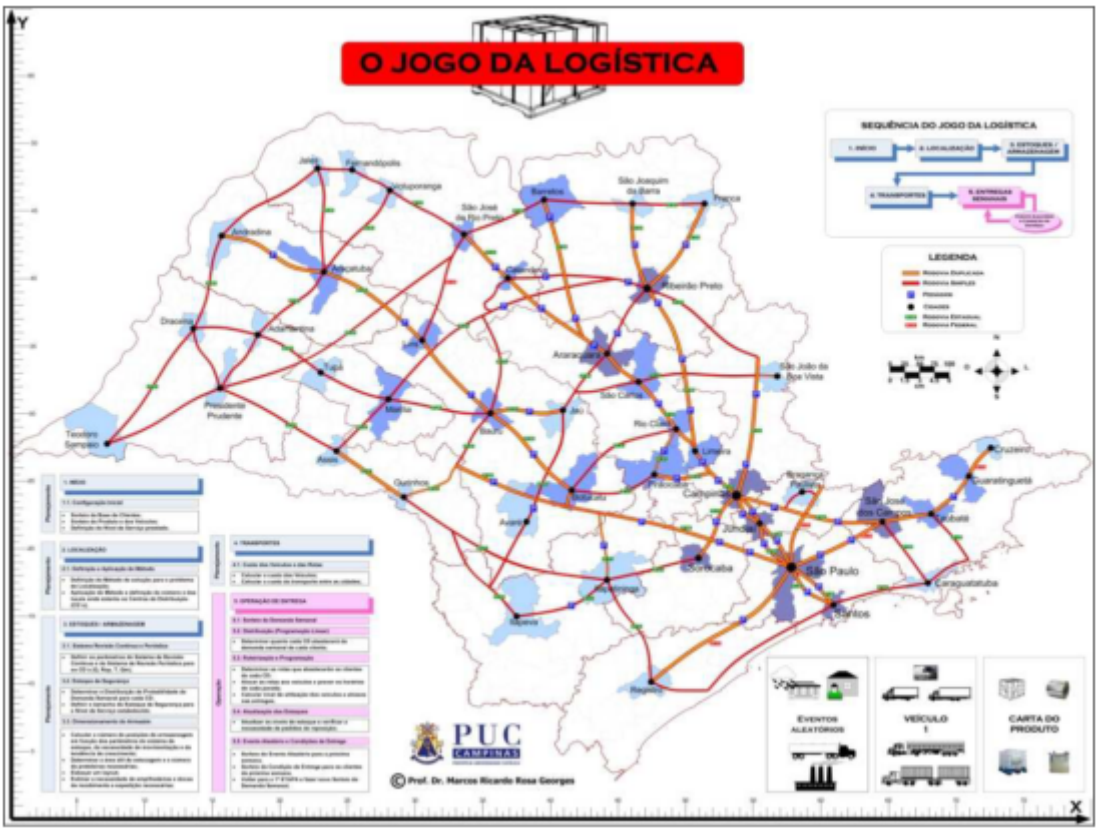



Figure 1 - Logistics Game Board (GEORGES, 2009)

The dynamics of the game, according to Table 2, is based on the information contained in cards for each stage of the game sequence, which is represented by the flow on the map itself. Table 1 shows the charts with the characteristics of cities, customers, products, transport vehicles, delivery conditions and random events (GEORGES, 2009).

Table 1 - Logistics Game Cards (GEORGES, 2009)

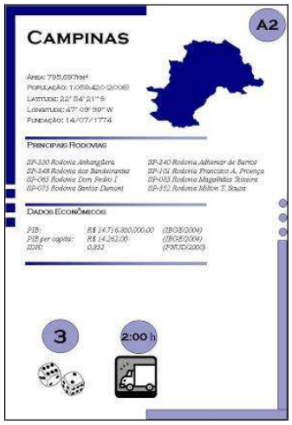
<table>
<tr><td colspan="3">CARDS</td></tr>
<tr><td>Clients<br> 
<br>Weekly demand<br>Location<br>Urban travel time</td><td>Products<br> 
<br>Physical characteristics (size and weight)<br>Market characteristics (price, storage costs and others)</td><td>Vehicles<br> 
<br>Technical specifications<br>Market data;<br>Waiting time</td></tr>
<tr><td>Delivey conditions<br> 
<br>Delivery days and times</td><td colspan="2">Random Events<br> 
<br>Internal and external events that compromise results and should be considered for solving problems</td></tr>
</table>

Table 2 - Sequence of the Logistics Game (GEORGES, 2009)

| | STAGE | DYNAMICS | APPROACHED CONCEPTS |
|---|---|---|---|
| **Stage** | Start | At this stage the student groups are formed and the customers and products are drawn for each team. Several customers are drawn by group, for CD location. | Step of planning the game itself. |
| | Localization | At this stage the groups should determine how many and which CD locations to serve customers and their demands | Various methodologies, extra game, are applied to determine the quantity and location of the |

| | | | |
|---|---|---|---|
| | | | CDs, according to (GEORGES, 2010) |
| | Inventory planning and warehousing | In this step, with the data of the customers and products, the inventory control and management system is determined, as well as the space required for storage. | Inventory control systems, continuous and periodic review, and security stock. These extra game calculations have textbook rationale (GEORGES, 2010) |
| | Transportation planning | Selection of transport vehicles according to the demands and characteristics of the products. | For vehicle selection and quantity the author GEORGES (2009) recommends reading textbook. |
| **Operations** | Weekly deliveries | This step is done after the draw of the demands for each customer and with the data of levels of stock in the CDs and transportation costs are calculated the deliveries that depart from each CD to meet the clients' weekly demands | This calculation is a classic transportation problem that is solved extra game with the help of the Excel solver supplement. The calculation of the delivery routes the author adopts method of the scan according to textbook adopted (GEORGES, 2009) |

After the steps of the planning phase the game has the rounds in the weekly delivery step, after completing this step, the demand cards are again drawn together with the random event cards and delivery condition. Thus changing the data and it is necessary to redo the calculations for new distribution of the products. According to GEORGES (2009) a number of rounds were not defined in the game until the end of the match.

### 4.2 Analysis of the Logistics Game

According to GEORGES (2009) the Logistics Game, even with its simple structure, allows a great flexibility in the deepening of topics as the contents of the discipline develops. The format of the board game still arouses curiosity even for students indifferent to the games, the author still mentions "Students are clearly seen postures as: initiative, leadership, take responsibility, commitment, ability to propose solutions, decision under pressure, among others "(GEORGES, 2009).

The Logistics Game allows students to develop social and behavioral skills such as teamwork, proactive posture, decision making, research, and self-learning. These skills are

developed by the active methodology based on problem-based learning (PBL), where through the playful aspects of the game are explored situations for the development of these abilities (GEORGES, 2010).

### 4.3 LEAN BOARD GAME

The Lean Board Game (LBG), created by GRUPO ENGENHO (2017) is a simulation game that has as background the layout of a factory where the production area and the support departments are represented: stock, receipt and dispatch. The goal of the game is, through a competition between teams, optimize production processes and financial results to the maximum, using the tools of "Lean Manufacturing" (MACHADO E CAMPOS, 2016). The game consists of a board (Figure 2) pieces (Figure 3), which represent machines, workers and inventories and murphy cards, which represent random events in demand and production.

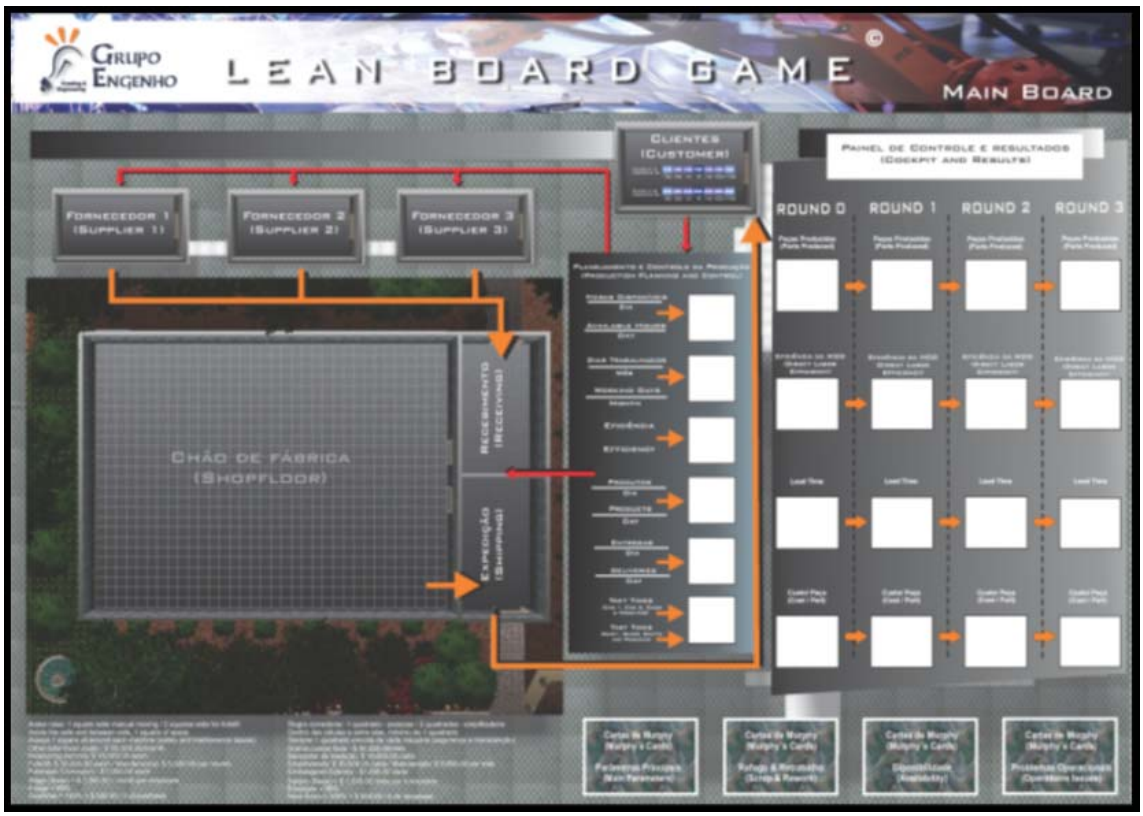



Figure 2 - Lean Board Game Game Board (GRUPO ENGENHO, 2017)

Figure 3 - Components of the Lean Board Game Game (GRUPO ENGENHO, 2017)

The game begins with a configuration of an initial problem scenario where the factory produces two products with four types of raw materials, but presents deficiencies in production to meet demand, financial loss and lack of physical space for expansion.

The dynamics of the game, shown in Table 3, is divided between the first round, where students must solve the current scenario, and the other rounds with the successive implementation of the proposed improvements using the Lean tools.

So after a few rounds the goal of the game is reached with the result of the implementation of the tools of "Lean Manufacturing" present in the LBG. It is still possible to use computational simulators as support for the decisions that must be taken with the implementation of the tools (MACHADO E CAMPOS, 2016).

Table 3 - Sequence of the game Lean Board Game (MORAES et al., 2013; MACHADO; CAMPOS, 2016)

| STEP | DYNAMICS | STEP EXITS | CONCEPTS |
|---|---|---|---|
| First Round | Groups should assemble the configuration of the initial problem scenario with information previously provided as: available capital, demand, available area and lottery of murphy cards. Also known are:<br>Product mix;<br>Costs of materials and labor;<br>Overhead costs;<br>Financing rate; Information for acquisition and productive characteristics of machinery and equipment;<br>Times for operations during production. | Definition of layout including corridors, circulation areas, stock areas and support areas;<br>Definition of shifts and workdays;<br>Acquisition of machinery and equipment;<br>Hiring of labor; Acquisition of ancillary resources;<br>Definition and acquisition of packaging;<br>Synchronization of productive areas;<br>Distribution of activities and processes.<br>Operational (efficiency, productivity and lead time) and financial analysis (profitability, labor costs, general costs and depreciation) of results | Knowledge and concepts of production engineering and lean production.<br>Planning and production control;<br>Layout;<br>Financial analysis |
| Next rounds | From the second round the teams apply the tools of "Lean Manufacturing". Each round, with the interference of murphy cards, the groups evaluate the interventions made and at the end of the fifth round wins the team that presents the best overall performance. | Each round after the application of the Lean Manufacturing tools present in the LBG, teams verify the impact on the performance indicators, and validate or not the actions taken. | Knowledge and concepts of production engineering and lean production.<br>Planning and production control;<br>Layout;<br>Financial analysis. |

### 4.4 Analysis of LEAN BOARD GAME

In the LBG game one can clearly see the application of the PBL methodology, where each round is proposed new challenges and the solution of these is guided by the teacher, who aligned as the methodology, initially contextualizes the problem for the students to develop, through a positive dispute between groups the solution of them, collaboratively and critical thinking to arrive at results that will again be analyzed and confronted with the theory. In addition to content learning, there is a strong development of students' social and behavioral skills (CONSTANTINO et al., 2016).

### 4.5 Mobility Game

Mobility Game is a board game to select modes of cargo transportation between a Cascavel-SC Distribution Center (CD) and the Paranaguá sea port. Developed at the Center for Mobility Engineering at the Federal University of Santa Catarina - Joinville Campus, according to VOIGT et al. (2013).

Board game with background the state of Paraná with two important routes of soybean, one by the road or another by the railway line, which connect the initial town Cascavel and the port of Paranaguá at the end. In the map (Figure 4) the different distances covered in the two modes and their respective problems are represented, which are visible in the board by the number of houses to go and the points that indicate obstacles, in order to bring the game closer to the reality of these modes. The objective of the game is to get to the port first with the lowest logistical costs, for this the game consists of board, pieces, cards, and spreadsheet to consolidate the results and reach the winner.


Figure 4 - Mobility Game Board (VOIGT et al., 2013)

The dynamics of the game (Table 4) is simple and based on a race with the positions of the competitors being played by luck, through the dice game.

Table 4 - Sequence of the Mobility Game (VOIGT et al., 2013)

| DYNAMICS | CONCEPTS |
|---|---|
| The beginning of the game is done through the draw of the objective cards (Figure 5) depending on the expected dynamics one can separate these cards in which they define or not the modal.<br>If the adopted objective is to select the modal, there is a "Transport Mode" Table (Figure 6) printed on the board itself, where there is capacity, freight and toll information. | Selection of modes according to cost and capacity. |
| The progress of the game is given by the draw of the number of houses, which the pieces must walk, by the launch of two dice, for the modal road and one given for the rail mode, thus simulating the speed of the means.<br>There are positions marked with obstacles (Figure 7) that interfere with the game and are determined by the symbols on the board, which the player must check for restrictions and penalties. When the player falls into the "Maintenance" box, he / she must pick up a maintenance card (Figure 8), regarding the mode, about the problem, the actions and cost to solve. | Characteristics of transport modes in Brazil. |
| The end of the game is due to the arrival of the players to the port, but the winner is the one who obtains the highest profit, by the sum of the data that is posted in the cost sheet, the amount receivable minus the expected and unexpected expenses. | Financial analysis. |


Figure 5 - Objective Charts (VOIGT et al., 2013)

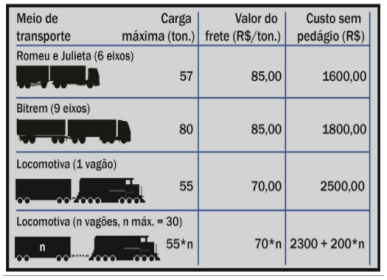



Figure 6 - Capacity and Costs (VOIGT et al., 2013)

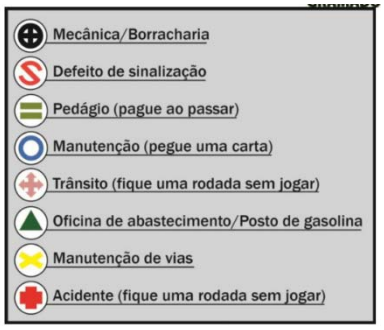



Figure 7 - Symbols of obstacles


Figure 8 - Maintenance Charts (VOIGT et

(VOIGT et al., 2013) al., 2013)

### 4.6 Analysis of the Mobility Game

The Mobility Game has a very simple gameplay, and its main function is to arouse students' interest in the study of the modal rail, even being a board game aroused great interest of the students who, through a survey, answered that the game has a dynamics that kept everyone's attention. The Mobility Game still contributes to the development of skills that are little approached in the conventional classroom (VOIGT et al., 2013).

## 5. CONCLUSON

Board games analyzed have different complexities, which can be understood as the set of game dynamics, the theoretical concepts presented, the means necessary to solve the problems and the number of rounds until the end of the game. In this way the LBG game can be classified as presenting high complexity; of medium complexity the Game of Logistics and low complexity the Game of Mobility. All have clear rules and defined objectives, as well as the characteristics of competitiveness and dispute between players or teams.

The game board is an effective resource in the introduction of an active learning methodology, in a playful way students are involved in a game dynamic where rules, luck and goals are mixed in a physical board, which represents a schematic system, or part of a process where there are problems to be solved and goals to be achieved, based on the PBL methodology.

One of the main characteristics of this type of game is its ability to stimulate the interpersonal relationship of the students, to solve the problems, through the formulation of strategies in group, besides a greater fixation of the didactic contents of the disciplines involved in the games by the practical application of the same ones , other skills developed by students are associated with communication skills, emotional intelligence, strategy, negotiation and others.

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